APPENDIX C

CASE HISTORY

PILE DRIVING AT LOCK AND DAM NO. 1
RED RIVER WATERWAY

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I. Introduction.

This case history report has been prepared to present an overview of problems associated with the driving of steel H-piles at the Red River Lock and Dam No. 1 in the New Orleans District of the Lower Mississippi Valley Division.

The discussion of problems encountered such as pile interference, piles hitting early refusal, driving with a vibratory hammer, etc., and the solutions and recommended preventive measures for these problems are presented for others who may encounter similar situations and benefit from this experience.

II. Description of Project.

Lock and Dam No. 1 is a feature of the Red River Waterway Project (Mississippi River to Shreveport), located in Catahoula Parish, Louisiana, approximately 5 miles north of the town of Brouillette. (See Figure C-1.) Navigation from the Mississippi River to the Red River is now provided through Old River via Old River Lock. The purpose of this project is to provide for navigation on the Red River from its junction at Old River up to Shreveport, Louisiana.

The Lock is a soil-supported reinforced concrete U-frame structure with a useable length of 685 ft and a width of 84 feet. The dam is a reinforced concrete structure with eleven 50-foot wide steel tainter gates. (See Figure C-2.) Both the dam structure and its stilling basin are supported on steel H-piles.

III. Phases of Construction.

To expedite the construction schedule for Lock and Dam No. 1 phased construction was necessary. A contract for the initial excavation and construction of the earthen cofferdam was awarded in June 1977 (Phase I). A second contract, which included installation of the dewatering system, structural excavation and construction, driving and testing piles, and driving of the dam service piles, was awarded in July 1978 (Phase II).

Although the specifications properly stated that the actual pile lengths would be determined from the test pile driving and loading, because of time constraints, production piles were ordered and purchased to the lengths as determined from soil parameters obtained from the soil borings. Numerous delays encountered by the Contractor in starting the pile driving led to the deletion of the driving of the service piles from this contract.

The third contract was awarded in December 1979. It consisted of all the remaining work and included the driving of the service piles which had to be incorporated into the final plans and specifications for this phase of construction (Phase III) due to its earlier deletion from Phase II.

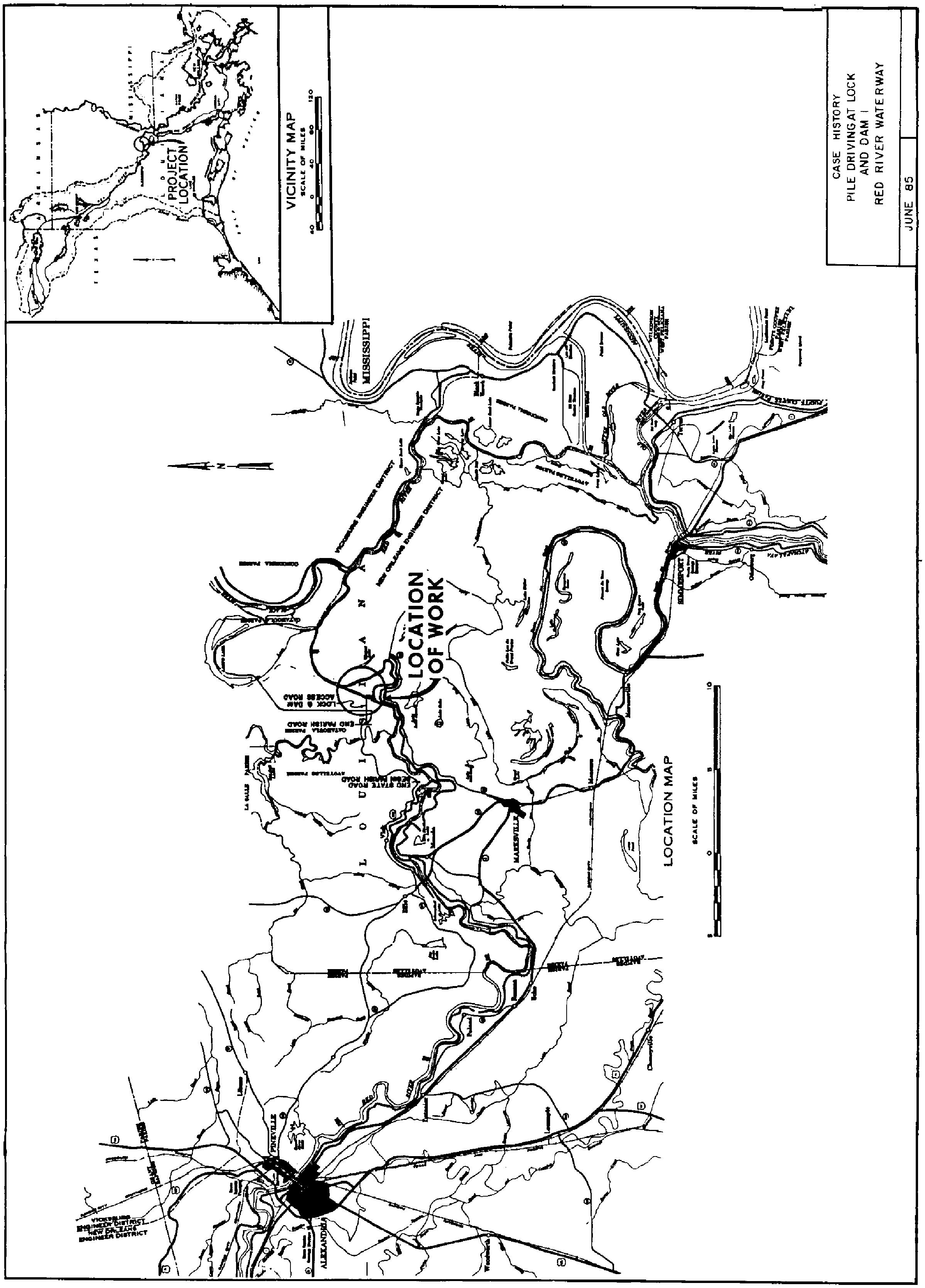


Figure C-1. Location map

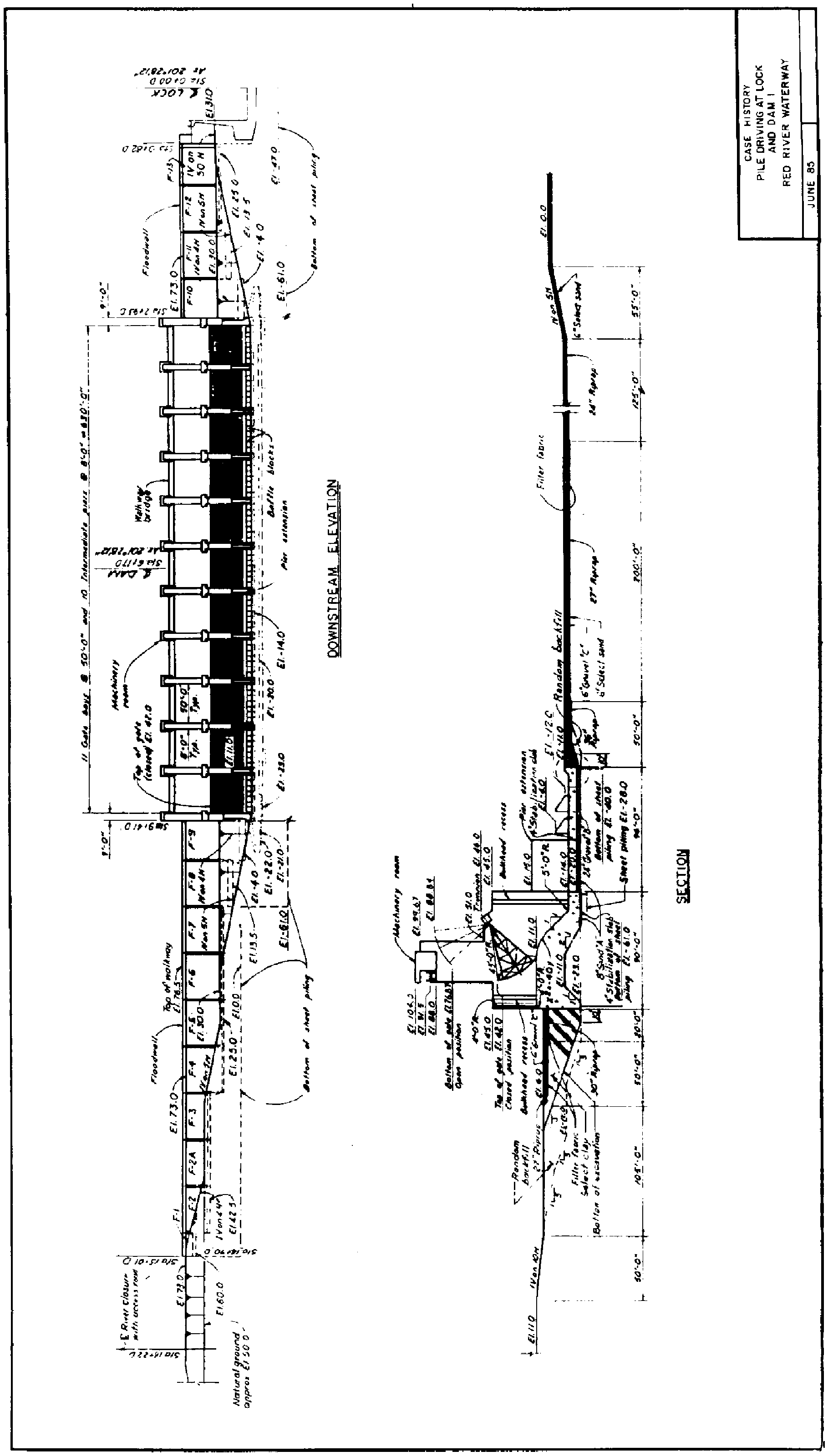


Figure C-2. Elevation and section of dam structure

IV. Soil Conditions.

A layer of medium to stiff holocene backswamp clays is located along the dam axis extending from the base of the dam (approximately -11 N.G.V.D.) to the top of the sand stratum (approximately elevation -48 N.G.V.D.). The bottom of this sand stratum extends to below elevation -140 N.G.V.D.

V. Driving Hammers.

The Phase II pile specifications allowed for the use of a vibratory hammer which the Contractor elected to use. Pile tests were to be performed on HP 14x89 and HP 12x53 steel H-piles. The Contractor drove the test piles using a Foster Vibratory Hammer Model 4000, having an eccentric moment of 4,000 inch-pounds and a weight of 18,800 pounds. Using this hammer, the 60 to 80 foot HP 12x53 test piling were driven in less than 2 minutes, while the 87 to 106 foot long HP 14x89 piling were driven in 10-16 minutes driving time. The various test piles were instrumented with "telltales" to determine the pile capacity in the various strata. Only load carrying capacity in the sand substratum was used in the design since it was determined that the long-term support capabilities of the overburden clays and silts would be negligible. The total pile support in the soil was to be developed by the skin friction in the sand and the pile tip bearing.

All compression pile tests were conducted 7 to 8 days after driving with tension pile tests conducted 11 to 15 days after driving. Two compression tests were conducted at site PT-1S on HP 14x89 piles 1-C and 2-C. The results of these tests indicated pile capacities of 63 and 83% of the computed theoretical capacity, respectively. At site PT-A, for 4 HP 12x53 piles (1-C, 2-C, 3-C, and 2C-X) tested in compression, the results were 37, 25, 40 and 57% of the computed theoretical capacities, respectively. In tension, the HP 12x53 pile 2C-X developed 30% of the computed capacity.

Retesting of some of the piles was directed to determine what effects elapsed time would have on the capacities of the piling. A compression retest, 25 days after driving, was made on HP 14x89 pile 1-C which originally tested at 63% of the computed capacity. The capacity of the pile increased from 63% to 78% of the computed capacity indicating a strength growth with elapsed time. The compression retests of two of the HP 12x53 piles resulted in increases from 37% to 70% of the computed capacity for pile 1-C, retested 70 days after driving; and from 40% to 78% for pile 3-C, retested 56 days after driving. Two tension pile retests were made, one test after 22 days had elapsed from the time of driving and the other test performed after 54 days had elapsed. An increase from 41% to 86% in HP 14x89 pile 2-C and an increase from 30% to 67% in HP 12x53 pile 2C-X of the computed capacity resulted for these two tension pile retests.

Consequently, the retests for both compression and tension test piles resulted in increased pile capacities with the passage of time for piling driven with a vibratory hammer. Figure C-3 is a table showing the capacities and dates driven for the tests and retests in compression and tension.

As a result of the pile tests and retests the service piling had to be approximately 12 feet longer than the computed theoretical lengths. As stated previously, the steel H-piling had been ordered and delivered prior to the pile tests, therefore splicing to obtain the additional length piling was

SITE	PILE NO.	PILE TYPE	PILE DATA BUTT ELEV	TIP ELEV	L	DATE DRIVEN	COMPUTED COMP. LOAD(TON)*	COMPRESSION TEST DATE	LOAD*	%**	COMPRESSION RE-TEST DATE	LOAD*	%**	COMPUTED TENSION LOAD(TON)	TENSION TEST DATE	LOAD	%**	TENSION RE-TEST DATE	LOAD	%**
PT-IS	I-C	14x89	-18.6'	-105.2	86.6'	7/9/79	176^T	7/17/79	110^T	63	8/3/79	137^T	78							
PT-IS	2-C	14x89	-18.7	-124.2	105.5'	7/9/79	228^T	7/16/79	190^T	83				126^T	7/20/79	51^T	41	7/31/79	108^T	86
PT-A	I-C	12x53	-20.1	-80.3	60.2'	7/11/79	87^T	7/19/79	32^T	37	9/19/79	60^T	70							
PT-A	2-C'	12x53	-20.8	-89.3	68.5'	7/11/79	110^T	7/18/79	26^T	25										
PT-A	3-C	12x53	-20.8	-89.0	68.2'	8/1/79	110^T	8/9/79	44^T	40	9/27/79	86^T	78							
PT-A	2C-X	12x53	-20.7	-99.2	78.5'	8/1/79	134^T	8/8/79	76^T	57				69^T	8/16/79	21^T	30	9/25/79	46^T	67

*LOAD IN SAND.

**PERCENTAGE OF COMPUTED LOAD

Figure C-3. Red River Lock 8 Dam No. 1 pile test summary necessary. The required splicing was performed in the storage area during the Phase III contract, increasing the maximum pile length from 96 feet to 108 feet.

The pile splice detail required a full penetration butt weld with 3/8-inch thick fish plates over the outside of the flanges (Figure C-4).

VI. Pile Layout.

The pile layout for the dam foundation consisted of alternating rows of batter piles, with a downstream batter of 2.5 vertical to 1 horizontal and an upstream batter of 4 vertical to 1 horizontal. (See Figure C-5 for typical layout.) Typical pile spacing between rows was 5 feet center to center. There were 904 HP 14x89 piles and 1,472 HP 14x73 piles in the dam foundation. The stilling basin, which consisted of predominantly 60-foot vertical piling, had 388 HP 14x73 piles and 633 HP 12x53 piles. (See Figure C-6 for typical layout.)

VII. Pile Driving Specifications.

The pile specifications allowed for a driving tolerance of 1/4 inch per linear foot along the longitudinal axis of the pile. A 3-inch tolerance in both X and Y directions in the position of the butt of the pile was allowed. The specifications also required that the pile be sufficiently supported in the leads.

Since the test piling were driven with a vibratory hammer, the specification for the Phase III contract mandated the use of a vibratory hammer with the same effective driving energy and efficiency. The Contractor elected to use an ICE (International Construction Equipment, Inc.) model 812 Vibratory Hammer. This hammer has an eccentric moment of 4,000 inch-pounds and weighs 15,600 pounds.

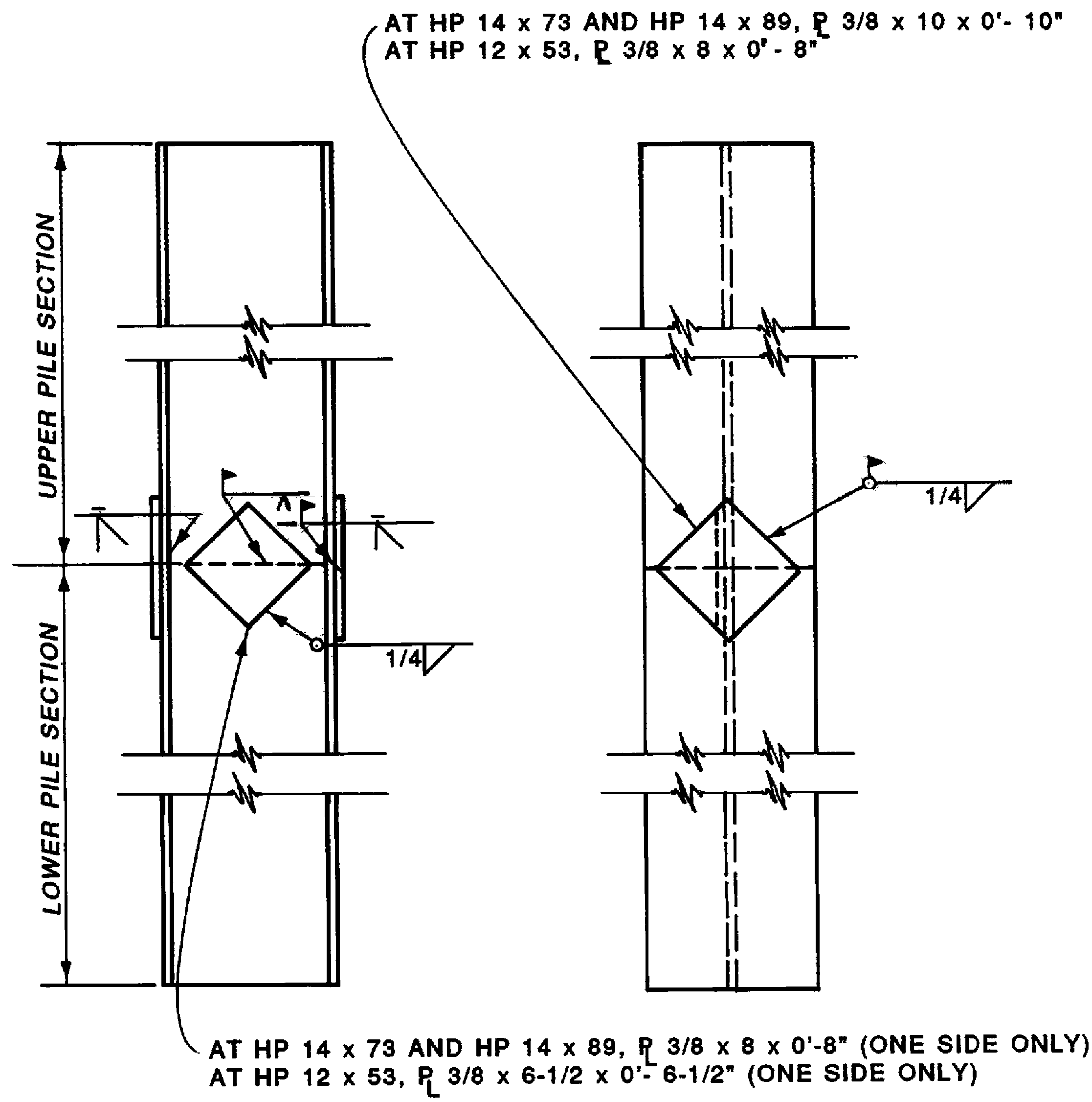
The Contractor’s driving equipment included two 4100 Manitowac Cranes fitted with International Construction Equipment (ICE) fixed leads and hydraulic spotters. An intermediate support was not provided in the leads, consequently the pile was supported only at the hammer and the ground, and was free to move between these two points.

VIII. Pile Driving.

Within the first few days of driving, several piles were reported to have reached refusal above final grade. The specifications defined refusal as a penetration rate of less than a tenth of a foot per minute. The piles reached refusal at depths ranging from 37 feet to 85 feet as measured along the length of the piling. Some of the piling that refused above the specified grade were ordered pulled. Upon examination of these piles it was apparent from the bottom damage that there had been pile interference during driving and collision with other piles.

A review of the Contractor’s driving procedures revealed the following:

a. The batter was set by using a 5-foot carpenter’s level with a template. The template, which was a triangle set to the prescribed batter,



NOTE: SPLICE LAYOUT IS TYPICAL FOR HP 14 x 73, HP 14 x 89 AND HP 12 x 53

Figure C-4. H-pile splice layout

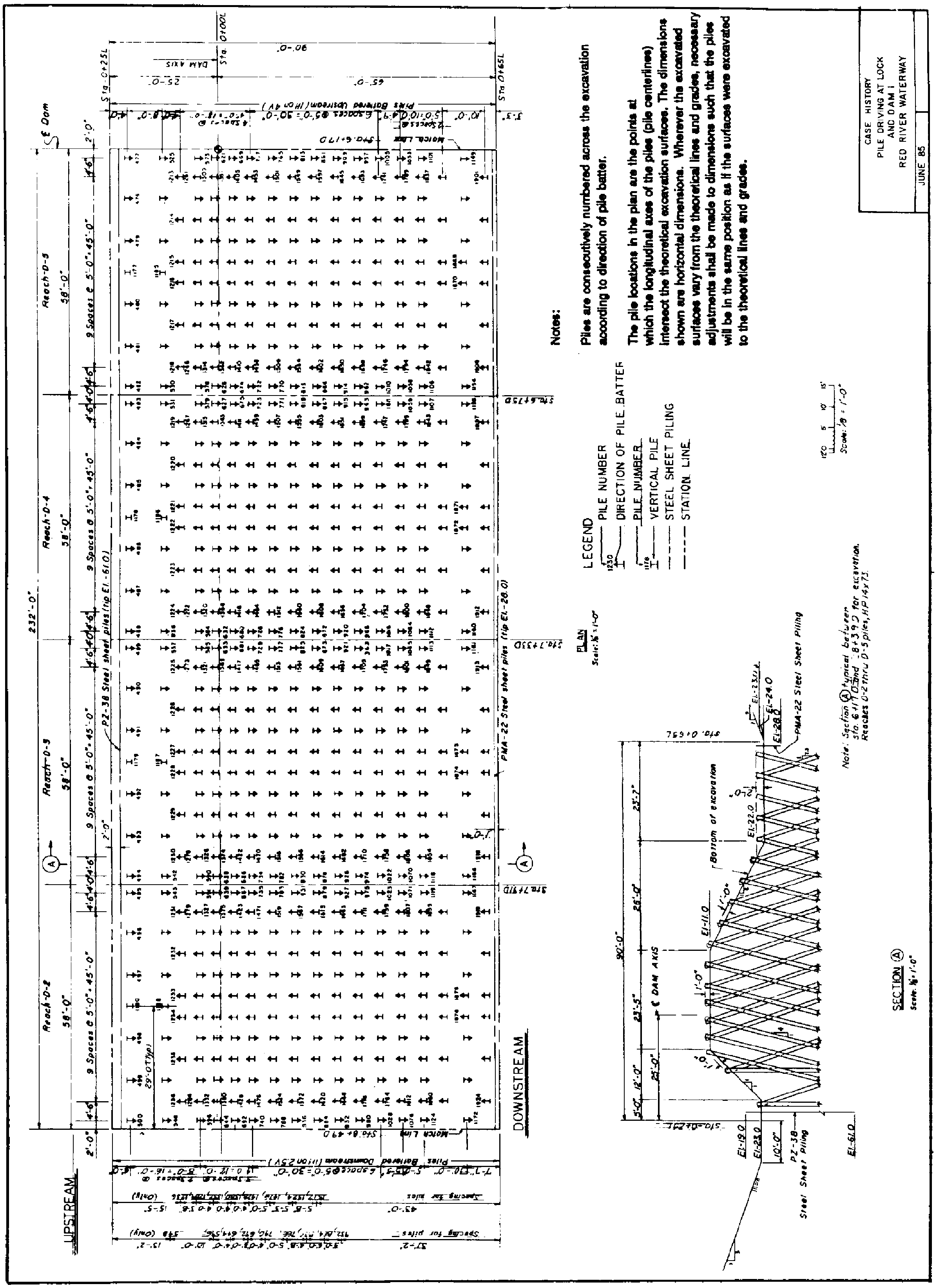


Figure C-5. Typical dam monoliths-pile layout

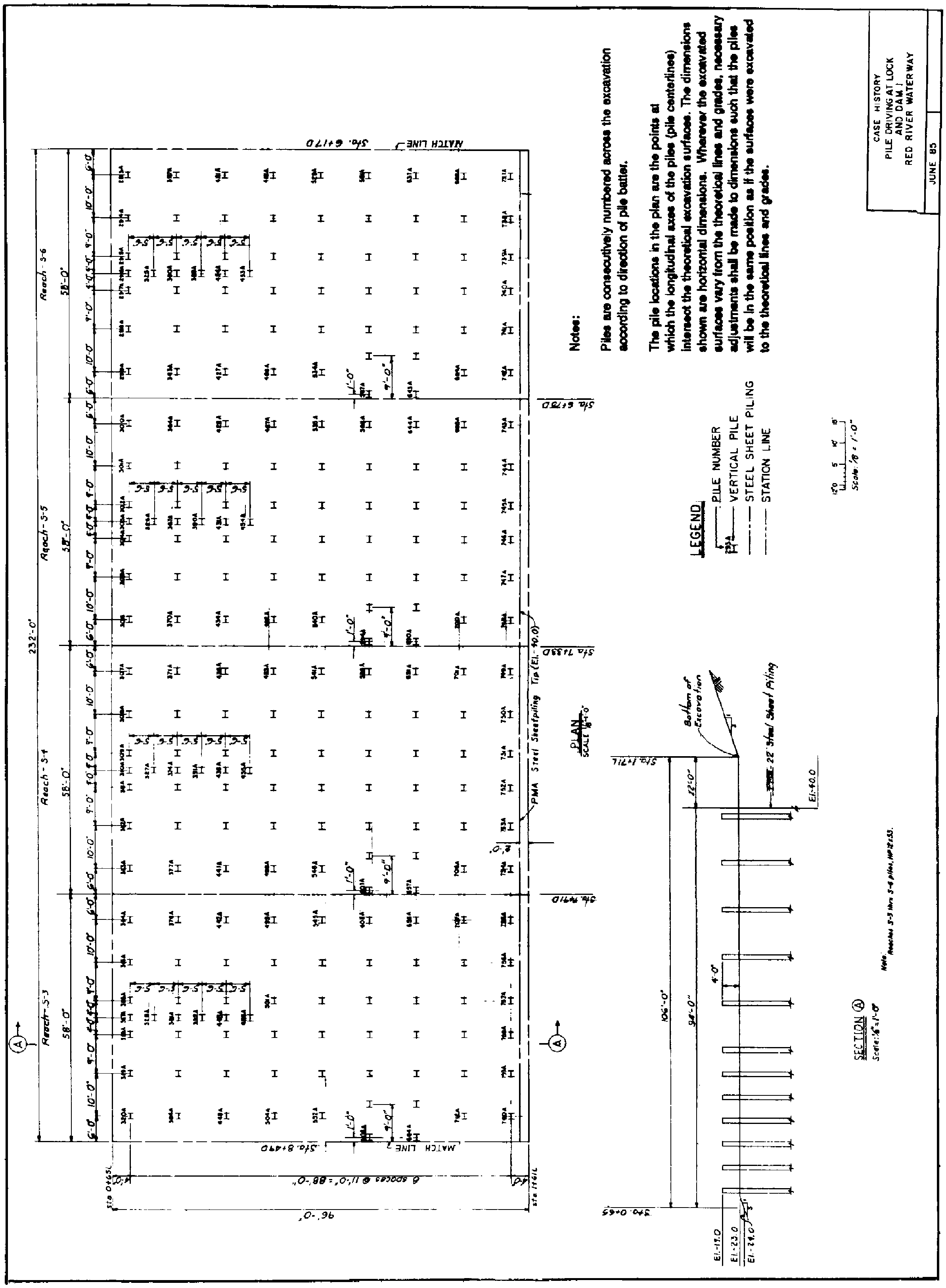


Figure C-6. Typical stilling basin monoliths-pile layout was placed against the leads, with a level used to plumb the vertical leg of the triangle.

b. Alignment of the pile along a line perpendicular to the axis of the dam was being accomplished by "eye-balling" the leads. Since a slight error in alignment would lead to pile interference, this method of alignment was not acceptable.

c. The Contractor was observed to be picking piles up at their ends in lieu of the specified one- and two-point pick up locations shown on the drawings. This method of pick up was causing excessive sweep in the piles.

d. Piling were being dragged one pile at a time with a front end loader from the storage area to the driving area. The lifted end of the pile was approximately 4 feet above the ground. This method of transport, along with improper storing, was causing damage to the piles. Permanent sweep of magnitudes 1-1/2 to 2 feet was observed on some of the piles.

e. During driving, the pilings were supported at the hammer and at the ground with no intermediate support point in the leads. Therefore, the piles which were 90-108 feet long had a tendency to buckle during driving. This buckling had the effect of increasing alignment problems.

It was concluded that the driving difficulties were caused by pile interference. Pile interference resulted from piles being driven off-line and/or driving of piles having substantial sweep caused by improper handling. The Contractor was directed to take the following remedial measures:

a. Use a transit to set the alignment of the piling perpendicular to the axis of the dam. Set up a transit on the pile-driving line, and by shooting the top and bottom of the leads, bring the pile into alignment.

b. Prior to driving, straighten all piles having more than 6" of sweep.

c. Revise all pile handling operations utilizing the one- and two-point pick ups shown on the plans.

d. Handle the piles such that deflections and/or bending stresses are resisted by the strong axis of the pile.

e. Add an additional pile support in the leads to support the piles at their midpoints.

IX. Piles Hitting Refusal.

Within the next several weeks after the above remedial measures were put into effect, additional piles hit refusal during driving. The pattern of refusal was very erratic. Piles adjacent to refused piles could possibly be driven to grade with no problem. On some occasions, refused piles could be pulled and redriven to grade within 1.5 feet of the original location. Average time of driving was approximately 7 minutes.

About this time several theories were developed as to the reasons for pile refusals; 1) the piles were refusing due to obstructions in the foundation; 2) the vibratory hammer was delivering insufficient energy to the pile tip; 3) or a combination of the above. Because of all these uncertainties, William A. Loftus, an expert in the field of pile driving was brought in by the New Orleans District for advice on the problem of pile refusals. After visiting the site and observing the Contractor’s pile driving operations, Mr. Loftus made the following observations and recommendations:

a. The corrective measures that were placed upon the Contractor had resulted in adequate control of pile alignment and placement. The possibility that sand densifications and obstructions in the sand stratum, such as gravel layers were more likely than had been expected from the pile tests and borings could be the cause of early pile refusal.

b. A load test of an in-place pile that reached early refusal should be made to determine the capacity.

c. Large diameter borings should be taken to determine the extent and size of gravel which was suspected as a cause of pile refusal.

The above recommendations were adopted, and six large-diameter borings were taken using a 3-inch spiltspoon and a 6-inch core barrel. Gravel zones were found to exist below elevation -85. The average size of gravel was 3/4 to 1-1/2 inches. Gravels larger than 2-1/2 to 3 inches were uncommon; however, cobbles as large as 4 inches were encountered. The original design borings were small diameter borings and could not detect these cobbles.

About 15 percent of the 2,376 piles in the dam foundation (excluding the shorter stilling basin piles which were not a problem) reached refusal above grade. Slightly less than 10 percent of the piles were cut off. Typically, about 20 feet of piling was cut off with the maximum being 40 feet. Shoes were used on about 10 percent of the piles. Compression and tension pile load tests were performed on a service pile that was cut off 12 feet above grade and a service pile that was driven to grade, and an evaluation of the as-built pile foundation with actual pile lengths was accomplished. This evaluation concluded that the pile foundation was safe and provided an adequate degree of stability for the dam monoliths.

X. Conclusions.

In reviewing the history of the pile tests, the driving procedure, the design, and the specifications for the Phase II and Phase III contracts for Lock and Dam No. 1, there are several factors that led to the many problems encountered during the pile driving operations. A sample pile specification which attempts to remedy these problems, is included as an attachment. This attachment was developed solely for this particular case history. Future projects should utilize the guide specification with appropriate modifications as necessary.

A. Factors Leading to Problems:

The vibratory hammer was very efficient in driving the piles to grade, but apparently reduced the capacity of the test piles. The phenomenon which causes this apparent loss of capacity is unknown, but there was sufficient evidence in the retests that showed a growth of pile strength with time.

Secondly, the Contractor started driving piling with very poor alignment and quality control procedures. This undoubtedly led to pile interference problems.

Thirdly, there existed cobbles in the foundation which were undetected by the original small diameter bore holes. These cobbles were the cause of early pile refusals after the Contractor’s pile driving procedures were improved.

B. Vibratory Hammer:

The vibratory hammer is a very efficient device for driving piles and therefore it’s use reduces pile driving costs. In addition to the driving economics of the vibratory hammer in a sand foundation, the hammer has other good attributes. These attributes include reduced noise, alignment control since the hammer grips the pile at its butt, and easier pile extraction since the hammer can be used without rerigging. Consequently, we should not indiscrimently prohibit its use. However, until further data are obtained for the vibratory hammer relative to reduced pile capacity, it is recommended that specifications allow the Contractor the option to use a vibratory hammer or a combination of the vibratory hammer with an impact hammer used for seating the piles with the following qualifications:

1. The Contractor perform duplicate pile tests for the vibratory hammer at his expense.

2. If increased pile lengths are required because of the vibratory hammer, the Contractor should bear the cost of the added lengths (specifications for the Old River Auxiliary Structures contained these stipulations).

C. Handling and Driving Piles:

It is extremely important that proper care should be taken in setting batters and aligning the piles. This is particularly important in congested pile foundations where a slight misalignment may cause pile interference. The specifications should require piles to be driven within a tolerance of 1/4 inch per linear foot of piling.

1. Piles with excessive sweep should be straightened before driving.

2. Intermediate supports in the leads should be provided to restrain piles from buckling during driving.

3. Care should be taken during driving, storing, handling, and transporting piles to avoid damage to the piling.

D. Sufficient Soils Data:

It seems that in the design of any foundation, there can never be too much information on the stratigraphy. A pile foundation is no exception. Where there is evidence of gravel layers or cobbles, it is recommended that large-diameter borings be taken to determine the extent and size of the gravel or cobbles.

E. Pile Refusal:

Refusal of piling in most instances is an indication of extreme point bearing capacity. Therefore, unless pile interference or a malfunctioning hammer system is suspected and the piling is not an uplift (tension) pile, it may be acceptable to cutoff the pile. For the refusal of tension piles, consideration has to be given to the number of piles that refuse, the required capacity and what reduction in safety factors can be accepted. If a large percentage of piles reach refusal, then an in situ pile test or changes in pile driving, e.g., hammer type of size, or use of pile shoes may be necessary. However, since construction delays are inherent in testing and the associated costs to the Contractor and to the Government are very high, this procedure should be used only when absolutely necessary.

F. Layout of Pile Foundation:

In the structural design and layout of the pile foundation, piles should be adequately spaced to allow for some pile drift. Although good pile alignment and batter can be achieved in the leads, it is virtually impossible to control or detect pile drift in the ground. It is recommended that the specified tolerance of 1/4 inch per linear foot of pile be used to determine the minimum pile spacing. Thus, if piling were 100 feet long, a minimum clear spacing of 50 inches would be provided to allow for the tolerance in each of the piles (2 x 100’ x 1/4").

ATTACHMENT

SECTION 2I - STEEL H-PILES

PART 1 - GENERAL

1. SCOPE. The work covered by this section consists of furnishing all plant, equipment, labor, and materials and performing all operations in connection with the installation of steel H-piles in accordance with these specifications and applicable drawings. Tension anchors are covered under SECTION 5J. The pile load and driving test program is covered in SECTION 2K.

2. QUALITY CONTROL.

2.1 General. The Contractor shall establish and maintain quality control for all operations to assure compliance with contract requirements and maintain records of his quality control for all construction operations, including but not limited to the following:

(1) Material
(2) Storing and handling
(3) Placing (location, alignment, etc.)
(4) Driving and splicing
(5) Cutting

2.2 Reporting. The original and two copies of these records and tests, as well as corrective action taken, shall be furnished to the Government daily. Format of the report shall be as prescribed in SP-16.

3. APPLICABLE PUBLICATIONS. The following publications of the issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the references thereto:

3.1 American Society for Testing and Materials (ASTM) Standards.

A 36-77a	Structural Steel

3.2 American Institute of Steel Construction (AISC).

Manual of Steel Construction, 9th Edition

4. SUBMITTALS.

4.1 Equipment Descriptions. The Contractor shall submit complete descriptions of pile driving equipment, including hammers, extractors, and other appurtenances to the Contracting Officer for approval 45 days prior to commencement of work.

4.2 Handling and Storage Plans. Proposed methods of handling and stockpiling the piles shall comply with requirements of 2I-6.4 and 2I-6.5 and shall be submitted in detail to the Contracting Officer for review and approval at least 45 days prior to delivery of the production piles to the job site.

4.3 Control of Placement. Proposed methods of controlling the location and alinement of the production piles shall comply with requirements of 2I-6.6

and shall be submitted in detail to the Contracting Officer for review and approval at least 45 days prior to driving the first production pile. Description of the alinement controls shall include the proposed methods of controlling the pile batter, the vertical plumbness, and rotation of the pile about the longitudinal centerline of the web.

4.4 Driving Record. The Contractor shall furnish daily to the Contracting Officer a copy of all driving data required in 2I-6.7.1. Unusual driving conditions, interruptions or delays during driving, and any other information associated with the pile driving operations shall be noted. The records shall be submitted in triplicate (original and two copies).

PART 2 - PRODUCTS

5. MATERIALS.

5.1 Steel. Steel for H-piles and splice plates shall conform to the requirements of ASTM A 36.

5.2 Steel H-Piles. Steel H-piles shall be of the shape and sections shown on the drawings. Piles shall have standard square ends, unless otherwise specified or directed. Lengths of piles shall be determined as specified below in 2I-6.3.1.

5.3 Pile Points. Pile points shall be Pruyn H-Pile Points, Type BP-75750, or approved equal.

5.4 Steel H-Pile Splices. Pile splice plates shall conform to details shown on the drawings. All welding shall be performed by certified welders as specified in SECTION 5E. The Government will test select splices by nondestructive methods.

5.5 Pile Tension Anchors. Pile tension anchors shall conform to details shown on the drawings. The Government will test the capacity of select tension anchors.

PART 3 - EXECUTION

6. INSTALLATION.

6.1 Pile Driving Equipment. Pile driving hammers shall be steam, air or diesel operated impact, single-acting, double-acting or differential acting type. Vibratory hammers will be allowed provided applicable requirements of SECTION 2K are satisfied. The production piles shall be driven with the same size and type hammer, operating with the same effective energy and efficiency as used in driving the steel test piles (which are covered in SECTION 2K). All pile driving equipment and appurtenant items shall be equal to that used in the test pile driving operations. The size or capacity of hammers shall be as recommended by the manufacturer for the pile weights and soil formation to be penetrated. Impact hammers shall have a minimum energy of 24,000 ft-lb for 14-inch H-piles and 19,500 ft-lb for 12-inch H-piles. The hammers shall be operated at all times at the speed and conditions recommended by the manufacturer. Boiler, compressor, or engine capacity shall be sufficient to operate the hammer continuously at full rated speed and inlet pressures. Once the actual driving has begun, all conditions (such as alinement, batter, cushions, etc.) shall be kept as constant as possible. Hammers shall have firmly supported leads extending to the lowest point the hammer must reach. In order to reduce the unbraced length of the pile during driving, the Contractor shall provide intermediate support for the pile in the leads at no additional cost to the Government. The Contractor shall submit details on intermediate supports to the Contracting Officer for approval.

6.2 Test Piles. All work associated with the required pile tests is covered in SECTION 2K.

6.3 Permanent Production Piles.

6.3.1 Lengths. The estimated quantities of piles listed in the unit price schedule are given for bidding purposes only. The Contractor shall not order piling until he receives a quantities list from the Contracting Officer as specified below. The Contracting Officer will determine the actual lengths of production piles required to be driven below cut-off elevation for the various locations in the work and will furnish the Contractor a quantities list which indicates lengths and locations of all piles to be placed. This determination will be made from the results of the pile driving and load tests performed as specified in SECTION 2K of this specification and will be provided to the Contractor as specified in SECTION 2K. Piling shall be furnished full length. Splicing of piling to make up the required lengths will not be permitted. The Contractor’s schedule shall be established to assure timely accomplishment of the pile tests, an essential item along the critical path.

6.4 Storing. Steel H-piles stored at the job site shall be stored on a level surface in an area that will not pond water and the piles shall be stacked in such a manner that all piles have uniform support along their length without sagging or bending. If it is not feasible to store the piles on a hard level surface, hardwood blocking shall be laid in such a manner so that piles are brought to level. Blocking shall be spaced at distances sufficiently short to prevent sagging or bending. In no case shall blocking be more than 10 feet apart nor more than 2 feet from the ends of the pile. The method of stacking shall not result in damage to the pile or excessive sweep or camber. Plan for storing H-piles shall be submitted as specified in 2I-4.2.

6.5 Handling. Pick-up points for steel H-piles shall be as shown on the drawings and shall be plainly marked on all piles. All lifting shall be done at these points. All lifting, except for lifting the pile into the driving leads, shall be accomplished using a two point pick-up. A one point pick-up may be used for lifting the pile into the driving leads. Pick-up devices shall be of the type that clamp to both pile flanges at each pick-up point. Use of alternate types of pick-up devices shall be subject to approval by the Contracting Officer. Burning holes in flanges or webs for handling shall not be permitted. During on-site transporting of piles, the piles shall be maintained in a straight position and shall be supported, as a minimum, at the quarter points. Dragging of piles across the ground shall not be permitted. Before the piles are transported from the stockpile area to the driving area, all piles shall be inspected for damage and excessive sweep and camber in accordance with these specifications and the drawings. The web and flanges of the piles shall be checked by rotating the pile with the pile resting on a firm level surface. A pile which has camber and/or sweep greater than 2 inches shall be rejected and shall not be transported to the driving areas.

A pile which is damaged and which in the opinion of the Contracting Officer is unusable, will be rejected, and shall not be transported to the driving areas. After the piles are delivered to the driving area, they shall be checked again, visually, to insure that damage has not occurred during handling and transporting from the stockpile area to the driving area. Any pile which is damaged and which damage, in the opinion of the Contracting Officer, renders the pile unusable and/or which contains excessive sweep or camber, as defined above, shall be replaced by a new pile at no additional cost to the Government. Proposed methods of handling shall be submitted as specified in 2I-4.2.

6.6 Placement. Piles shall be accurately placed in the correct location and alinements, both laterally and longitudinally and to the vertical or batter lines as shown on the contract drawings. To insure correct placement of piles, the Contractor shall establish a rectangular grid system by use of a surveying instrument having at least the accuracy of a one-second Theodolite. The Contractor shall check each pile, prior to driving and with the pile head seated in the hammer, for correct batter, vertical plumbness, and rotation of the pile about the centerline of the web. The vertical plumbness of the pile shall be checked with a surveying instrument having at least the accuracy of a one-second Theodolite to insure that the pile is being driven parallel to the grid line in the direction of the pile batter. A lateral deviation from the correct location at the cut-off elevation of not more than 3 inches will be permitted. A vertical deviation from the correct cut-off elevations shown on the drawings of not more than +2 inches will be permitted. A variation in alinement of not more than 1/4-inch per foot of longitudinal axis will be permitted. Moving the pile by rotating the leads, pulling on the pile, and wedging the pile will not be allowed. If, during driving, the pile shifts or otherwise moves beyond the specified tolerances, the Contractor may be required to pull and redrive the pile as directed by the Contracting Officer. Piles which are misplaced shall be pulled and redriven at no additional cost to the Government. Any voids that remain after pulling misplaced piles shall be filled with sand, and all costs related thereto shall be borne by the Contractor.

6.7 Pile Driving.

6.7.1 Driving. No piling shall be driven within 100 feet of any concrete structure, unless authorized by the Contracting Officer. A complete and accurate record of the driving of piles as specified in 2I-4.4 shall be compiled by the Contractor for submission to the Contracting Officer. This record shall include pile dimensions and locations, the description of hammer used, rate of hammer operation, for impact hammers the number of blows required for each foot of penetration throughout the entire length of each pile, for vibratory hammers the cumulative time of penetration at five foot intervals shall be recorded throughout the entire length of each pile, butt elevation upon completion of driving and any other pertinent information requested by the Contracting Officer. When driving long piles of high slenderness-ratio, special precautions shall be taken to insure against overstressing and leading away from a plumb or true position. During driving, pile driving hammers shall be operated at all times at the speed, inlet pressure, and conditions recommended by the hammer manufacturer. Each pile shall be driven continuously and without interruption to the minimum required depth of penetration. Deviation from this procedure will be permitted only for cases where interruptions due to splicing as described below or the driving is stopped by causes which reasonably could not have been anticipated. If the pile is driven with an impact hammer to the minimum depth of penetration but the minimum penetration per blow has not been attained, the pile shall be driven deeper as necessary to attain the minimum penetration per blow. The minimum penetration per blow will be determined by the Contracting Officer upon completion of the pile tests. A pile which has not reached the minimum penetration rate per blow when the top has been driven to the cut-off elevation shall be spliced as shown on the drawings and driven to a depth sufficient to develop the minimum penetration rate per blow. All pile splices shall be fabricated by qualified welders. For impact hammers, when the maximum permissible blows of 17 blows per inch for 3 consecutive inches (single-acting) or 20 blows per inch for 3 consecutive inches (double-acting) is reached above the minimum tip elevation, the pile shall be pulled and redriven or shall be cut off and either used or abandoned, as directed by the Contracting Officer. For vibratory hammers, when the tip does not move more than 0.1 foot per minute, the Contractor shall immediately attempt driving of the pile with an impact type hammer conforming to 2I-6.1. If redriving is necessary, piles shall be redriven at a site specified by the Contracting Officer. Piles which have been uplifted after driving shall be redriven to grade after conclusion of other driving activity in that general area. if backdriving is required an equitable adjustment in contract time and price will be made in accordance with the General Provision Clause "Changes". Jetting shall not be used to assist driving the piles. Pile points shall be installed only when directed by the Contracting Officer. Method of installation shall be as recommended by pile point manufacturer.

6.7.1.1. The Contracting Officer may require that any pile be pulled for inspection. Any pile which is damaged because of internal defects or by improper handling or driving or is otherwise damaged so as to impair it for its intended use, shall be removed and replaced. Piles pulled at the direction of the Contracting Officer and found to be in suitable condition shall be re-driven to the required depth at a site specified by the Contracting Officer. Any pile that cannot be driven to the required depth because of an obstruction shall be pulled and redriven at a site specified by the Contracting Officer. Payment for pulled piles will be made in accordance with 2I-8.3.

7. MEASUREMENT.

7.1 Steel H-Piles. Measurement for furnishing and delivering steel H-piles will be made by the linear foot for steel H-piles acceptably delivered at the site. Steel H-piles driven with an impact hammer will be measured for payment on the basis of lengths along the axis of the pile in place below the cut-off elevation. Steel H-piles driven with a vibratory hammer will be measured for payment on the basis of pile lengths determined from the testing program for piles driven with an impact hammer, see SECTION 2K. Pile lengths will be measured to the nearest tenth of a foot.

8. PAYMENT.

8.1 Furnishing and Delivering Piles. Payment for furnishing and delivering steel H-piles, at the site, will be made at the applicable contract unit prices for:

"Furnish and Deliver Steel H-Piles (HP 14 x 89)",
"Furnish and Deliver Steel H-Piles (HP 14 x 73)", and
"Furnish and Deliver Steel H-Piles (HP 12 x 53)".

Payment for furnishing and delivering will be made after proper storage of the piling.

8.1.1 Driving Piles. Payment for the measured length of each pile acceptably driven will be made at the applicable contract price per linear foot for "Drive Steel H-Piles (HP 14 x 89)", "Drive Steel H-Piles (HP 14 x 73)", and "Drive Steel H-Piles (HP 12 x 53)". These prices shall include all items incidental to driving the piles and cutting off all piles at the cut-off elevation. Payment for furnishing and installing tension anchors will be made according to SECTION 5J. No additional payment will be made for the use of an impact hammer on piles which have refused with a vibratory hammer. Payment for furnishing and driving test piles will be made according to SECTION 2K.

8.2 Reserved.

8.3 Pulled Piles.

8.3.1 Undamaged Pile. Piles which are pulled at the direction of the Contracting Officer and found to be in good condition will be paid for at the applicable contract unit price for "Furnish and Deliver Steel H-Piles" and "Drive Steel H-Piles" in its original driven position. The cost of pulling and backfilling with sand, if applicable, will be paid for at the applicable contract unit price for "Drive Steel H-Piles". Such pulled piles when re-driven will be paid for at the applicable contract unit price for "Drive Steel H-Piles".

8.3.2 Damaged Pile. Where a pile is pulled and found to be defective and or damaged due to Contractor negligence or internal defects, no payment will be made for either originally furnishing and driving such pile or for the operation of pulling and backfilling with sand, if applicable, and it shall be replaced by a new pile which will be paid for at the applicable contract unit prices. Piles which are pulled and found to be damaged through no fault of the Contractor will be paid for the applicable contract unit price for "Furnish and Deliver Steel H-Piles" and "Drive Steel H-Piles" in its originally driven position. The cost of pulling and backfilling with sand, if applicable, will be paid for at the applicable contract unit price for "Drive Steel H-Pile". A new pile shall be driven in place of the defective and/or damaged pile and will be paid for at the applicable contract unit prices.

8.4 Steel H-Pile Splices. For each pile splice directed by the Contracting Officer, payment will be made at the rate of $200 per splice. This price shall include the cost of furnishing all plant, labor and material required to make the directed splices.

8.5 Pile Points. If pile points are required, as directed by the Contracting Officer, payment will be made at the rate of $150 per pile point. This price shall include all costs incidental to furnishing and properly installing the pile points on the pile.